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ROHM & HAAS COMPANY

REDSTONE ARSENAL RESEARCH DIVISION

HUNTSVILLE, ALABAMA

S-28

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AN EVALUATION OF SAFETY DEVICES FOR LABORATORIES HANDLING EXPLOSIVE COMPOUNDS

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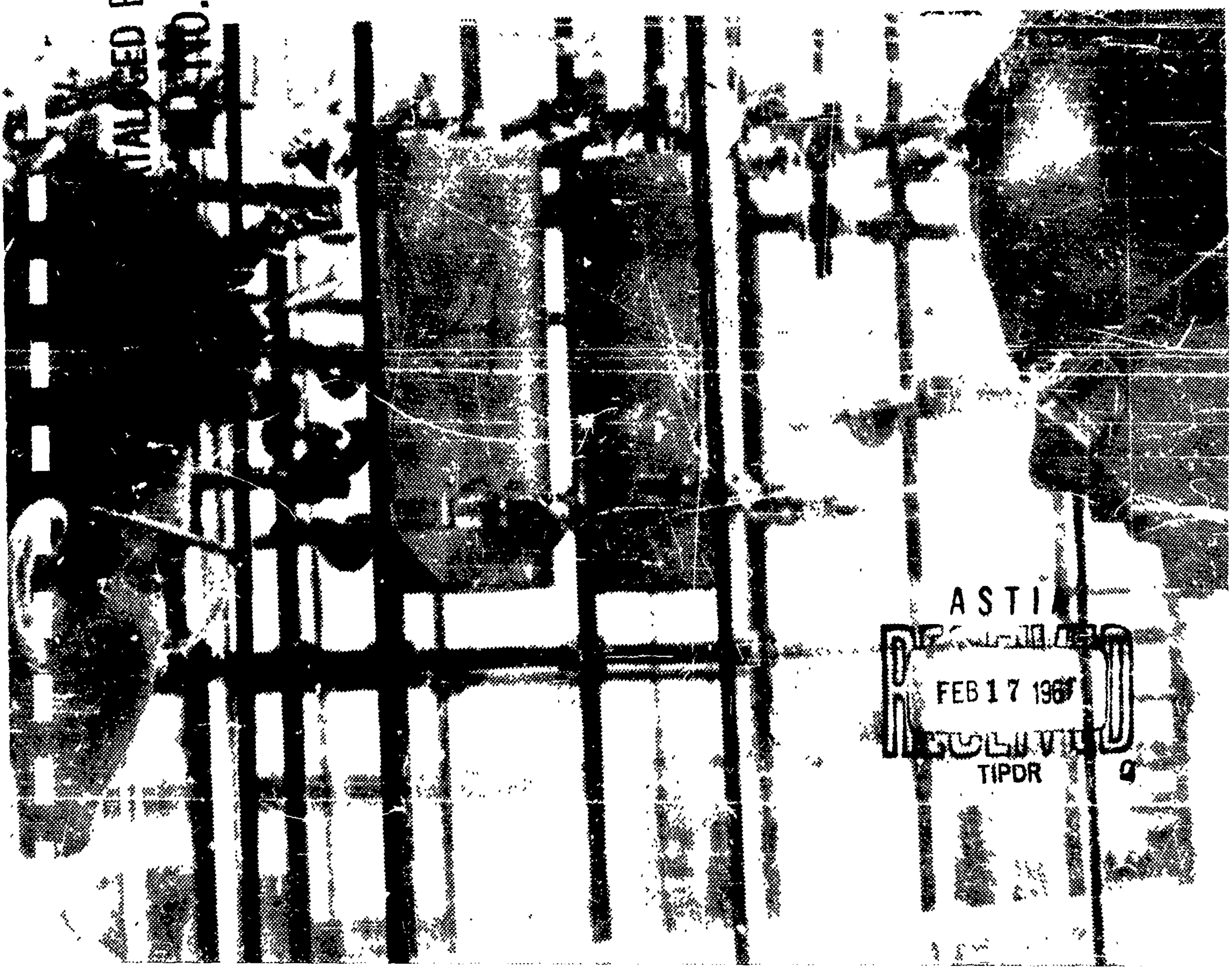

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AN EVALUATION OF SAFETY DEVICES FOR LABORATORIES HANDLING EXPLOSIVE COMPOUNDS

Contributing Staff:

James P. Dodrill

Charles E. Green

James F. Hester

Charles R. Wells

Approved:

Allen R. Deschere
General Manager

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FOREWORD

In September 1958 this Division published Report S-18 "An Evaluation of Safety Goggles and Safety Shields". Since that time additional tests were carried out on laboratory safety shields and the study of protection afforded by various pieces of laboratory safety equipment was extended to gloves, sample transporting containers, and remote manipulators. All material in S-18 is reproduced in this report.

TABLE OF CONTENTS

I. Introduction

Laboratory studies directed toward the synthesis of new propellant ingredients frequently produce products having considerable explosive potential, and unknown sensitivities to detonation. Consequently all reactions and products must be assumed capable of explosion or detonation at any time, and precautions taken accordingly. Equipment is usually assumed to be expendable, but personnel must be adequately protected.

Personnel protection is gained in two ways: through the use of protective clothing and personal equipment, and by the use of shields designed to isolate hazardous reactions. Past practice in the use of personal protective equipment and shields has not been particularly sophisticated; goggles, flame-proofed garments, gauntlets, and shields were used, and reactions were run with the minimum quantities of material, but few data were available as to the amount of protection these safety devices offered. Several explosions and fires in the industry indicated that the desired degree of protection was not always obtained with safety equipment.

This Division initiated a program designed to give a quantitative measure of the protection offered by various types of safety equipment. Included in this evaluation were safety goggles[1], shield materials, shields, gloves, remote manipulators, and explosives carriers.

II. Personal Protective Equipment

A. Safety Goggles

Twenty types of goggles (Table I) were tested for sensitivity to flame and impact.

For the flame tests an 80-g. charge of composite propellant was burned in a 14-in. length of 6-in. diameter water pipe sealed at one end. The full blast of the flame was directed at a department store mannequin head

[1]Material on safety goggles and shield materials was published previously in Rohm & Haas Co., "An Evaluation of Safety Goggles & Safety Shields", Report No. S-18, September 1958. The whole of this report is reproduced here in order to assemble in one place all work of this Division on laboratory safety equipment.

Table I

Types of Goggles Tested

Type A	American Optical Company Rubber Frame Goggles (w/vent. slots) Catalogue No CE-33610 (Plastic lenses and rubber frame) Supplier Mine Safety Appliance Co
Type B	Willson Rubber Mask Goggles Style No X4 (Safety glass lenses and rubber frame) Supplier Safety Engineering and Supply Co
Type C	Saf-I-Shield Catalogue No 2210 (Optil'te lenses and rigid plastic frame) Supplier. U S Safety Service Co
Type D	Bai-Guard Eye Shield W-32 (w/clear lenses) Cellulose plastic lenses and rigid plastic frame) Supplier Bausch and Lamb Optical Co
Type E	Willson Mono-Goggle Style No 101 (Plastic lenses and polyethylene frame) Supplier Safety Engineering and Supply Co
Type F	Saf-I-Shield Catalogue No 2200 (Optilite lenses and rigid plastic frame) Supplier U S Safety Service Co
Type G	Saf-I-Flex Catalogue No 291004 (Optilite lenses and polyethylene frame) Supplier U S Safety Service Co
Type H	Panoram Goggles (large) CE-34250 Plastic lenses and rigid plastic frame) Supplier Mine Safety Appliance Co
Type I	Panoram Goggles (small) CE-33825 (Plastic lenses and rigid plastic frame) Supplier Mine Safety Appliance Co
Type J	One piece, All Plastic Goggle Catalogue No CE-34249 (Plastic lenses and polyethylene frame) Supplier: Mine Safety Appliance Co
Type K	Willson Mono Goggle, Style 51 (Plastic lenses and polyethylene frame) Supplier Safety Engineering and Supply Co
Type L	Jones Clearview Visor Goggle Model No 1 (Plexiglas lenses and polyethylene frame) Supplier. Mine Safety Appliance Co
Type M	Cesco Cover'lite Goggles No 562 (Super safetyglass lenses and rigid plastic frame) Supplier Guardian Supply and Equipment Co
Type N	Willson Goggle Type WK 847 (Super-tough safety glass and rigid plastic frame) Perforated plastic sideshields Supplier Willson Products, Inc.
Type O	Saf-I-Chem, No 283608 (Plastic lenses and polyethylene frame) Supplier Safety Service Co
Type P	Saf-I-Flex, No. 293607 (Plastic lenses and polyethylene frame) Supplier:U S Safety Service Co.
Type Q	Saf-I-Flex No. 295004 (Plastic lenses and polyethylene frame) Supplier U S Safety Service Co
Type R	Saf-I-Flex, No. 295123 (Plastic lenses and polyethylene frame) Supplier U. S. Safety Service Co
Type S	Softsides Goggles, No CE-36316 (Plastic lenses and polyethylene frame) Supplier Mine Safety Appliance Co
Type T	Softsides Goggles, No CE-36120 (Plastic lenses and polyethylene frame) Supplier. Mine Safety Appliance Co

set 18 in. from the end of the pipe. The face on the mannequin was built up with modeling clay to allow the goggles to be tightly fitted. Absorbent cotton balls were placed in the eye sockets of the mannequin head, the goggles fixed in place over the eyes, and the goggles subjected to one blast of flame from the front and another blast from the side. After each flash, the goggles were removed and the result of the test recorded (Table II). Damage to the cotton balls was divided into two categories: scorching and burning. Scorching included all conditions from slight discoloration to slight charring. Burning included those instances in which the cotton ball was completely consumed (Figs. 1-3).

For the impact test the goggles were clamped by the frames in a semi-rigid position and fired on at a range of 90 feet with a 12-gauge shotgun loaded with 3-1 1/8-8 Scatter-load shells. The resulting damage was recorded (Figs. 4-24).

Table II

Damage Resulting from Flame Tests

Type	Full Face Left Eye Scorch	Full Face Left Eye Burn	Full Face Right Eye Scorch	Full Face Right Eye Burn	Side Left Eye Scorch	Side Left Eye Burn	Side Right Eye Scorch	Side Right Eye Burn
A								
B								
C							X	
D								
E					X		X	
F								
G								X
H		X	X		X		X	
I	X		X		X		X	
J								X
K								X
L								X
M	X		X				X	
N		X	X			X		X
O								
P								
Q			X		X		X	
R	X							
S (w/.050 pvc lens)								
S (w/.050 pva lens)	X		X		X			
T (w/.050 pvc lens)							X	
T (w/0.050 pva lens)								
S '0.060 cellulose acetate lens)								

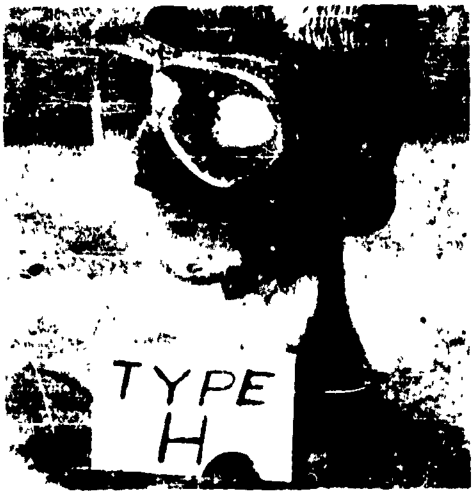

Fig. 1 Cotton eyes before test.

Fig. 2 Blast from burning propellant striking goggles.

Fig. 3 Face after test with goggles removed. Cotton in one eye was burned out.

Fig. 4 Type A goggle hit by five pellets-all five repelled-one produced 90° crack with 1/2-inch legs.

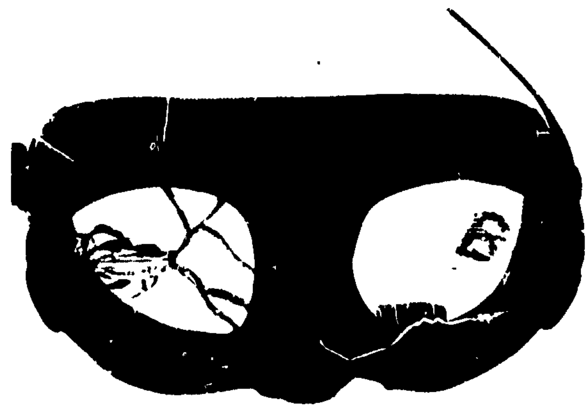

Fig. 5 Type B goggle hit by two pellets-both repelled, but the right lens was shattered with a small amount of spalling.

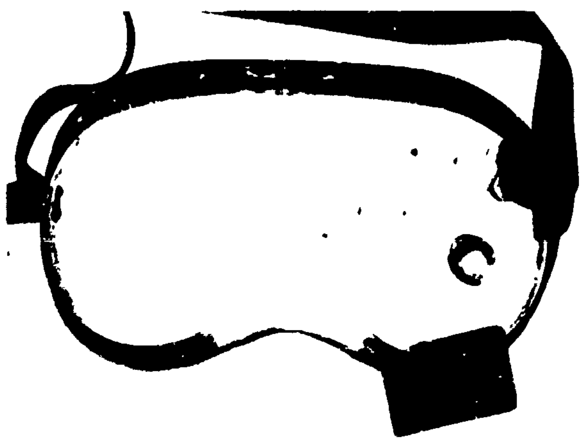

Fig. 6 Type C goggle hit by four pellets-all four repelled.

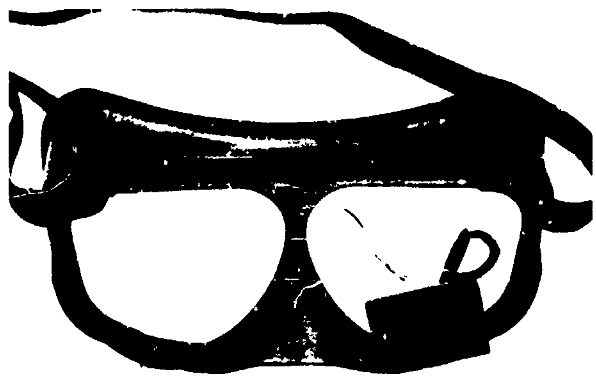

Fig. 7 Type D goggle hit by eight pellets-all eight repelled-one produced straight 1-1/4 inch crack.

Fig. 8 Type E goggle hit by three pellets-one repelled-other two pellets made clean 1/4 inch holes

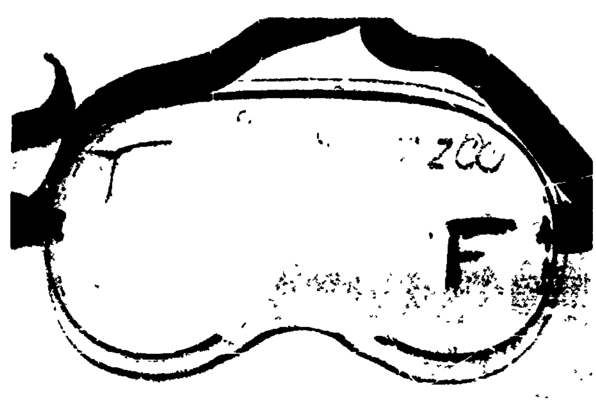

Fig. 9 Type F goggle hit by three pellets-all three pellets repelled-one pellet produced three radial cracks of 1/2" X 1/2" X 1/4"

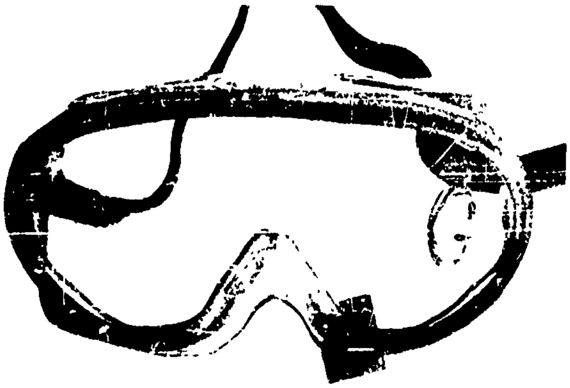

Fig. 10 Type G goggles hit by six pellets—all six repelled—one produced 1/4 inch cruck in edge of lens.

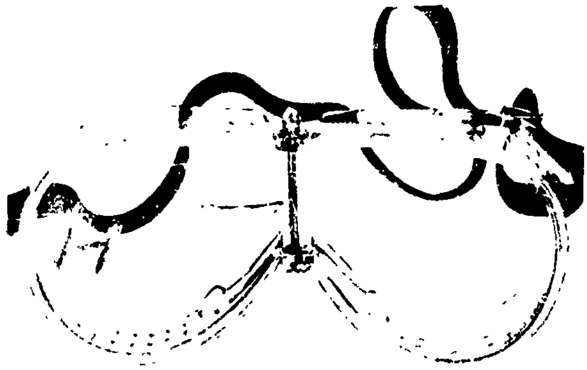

Fig. 11 Type H goggle hit by six pellets—three were repelled after producing cracks, three knocked out 1"X 1/2" piece of lens.

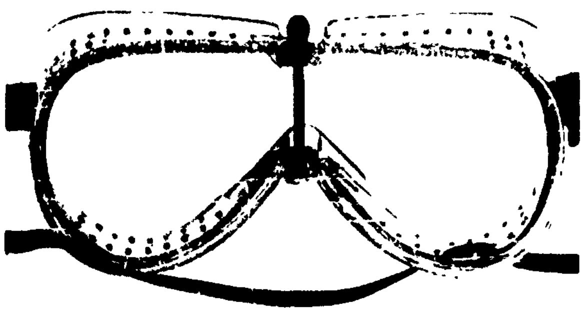

Fig. 12 Type I goggle impossible to determine how many hits—left lens was shattered and knocked out—other lens not hit.

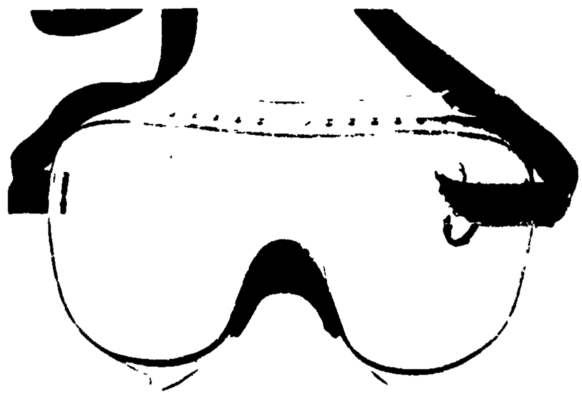

Fig 13 Type J goggle hit by four pellets—all four were repelled.

Fig. 14 Type K goggle hit by five pellets all five were repelled.

Fig 15 Type L goggle hit by three pellets—all three produced serious radial cracking upon being repelled—potential shatter

Fig 16 Type M goggle apparently hit by two pellets—one shattered left lens—other pellet only marked the right lens.

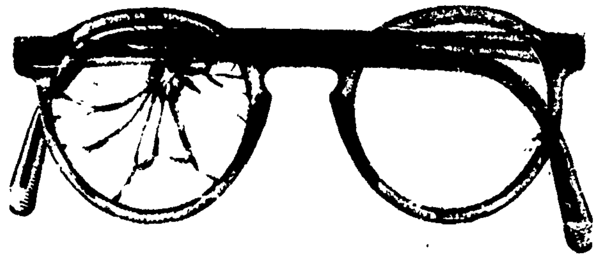

Fig. 17 Type N goggle hit by two pellets—one pellet shattered right lens—other lens dropped out of frame when frame was severed by second pellet.

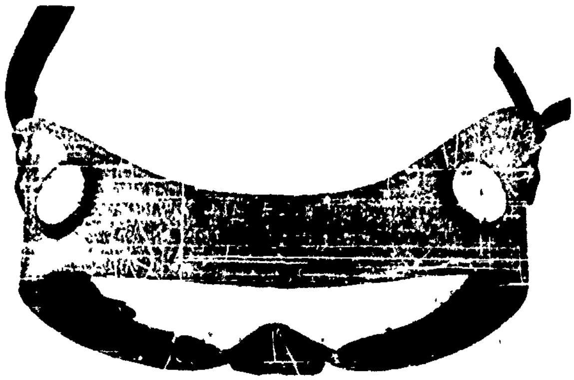

Fig. 18 Type O goggle hit by seven pellets—al seven repelled.

Fig. 19 Type P goggle hit by ten pellets—all ten repelled—one pellet produced a straight 1/2-inch crack

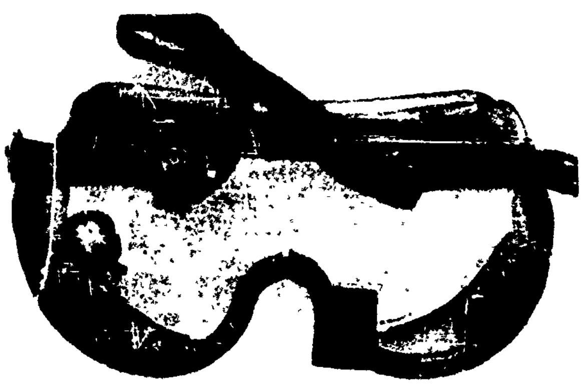

Fig. 20 Type Q goggle hit by four pellets—all four repelled.

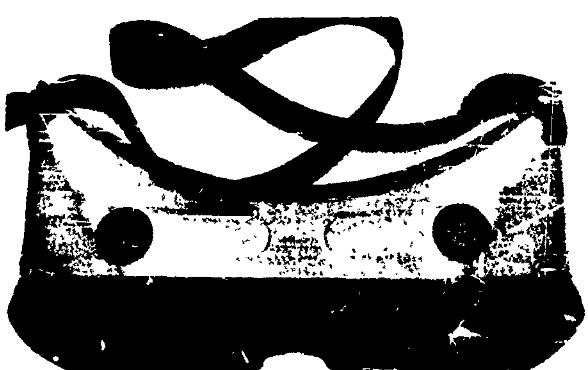

Fig 21 Type R goggle hit by five pellets - all five repelled

Fig. 22 Type S (With .050 PVA Lens) goggle hit by eight pellets-all eight repelled.

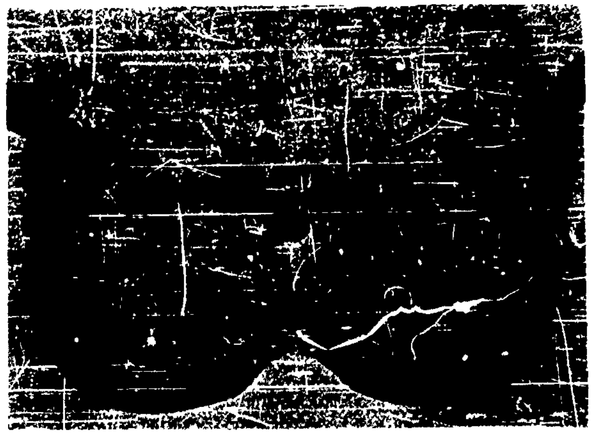

Fig. 23 Type T (With .050 PVC Lens) goggle hit by six pellets-five produced clear 1/8" holes.

Fig. 24 Type T (With .030 PVC Lens) goggle hit by two pellets-both produced clean 1/8" holes.

B. Safety Shields

1. Shield Materials

Commercially available transparent safety shields for laboratory use generally consist of laminated safety glass held in a light metal frame and supported by a moderately heavy base. Other shields are made to serve a particular purpose and may be made from a variety of materials; size is generally determined by the hazard which is to be shielded against. The Ordnance Safety Manual, ORD M 7-224,

merely indicates that safety shields must be adequate as determined by tests.

> "Shields for protection against items containing less than 15 pounds of explosives may be of steel or other suitable material. The adequacy of these operational shields, including thickness, size, fastening, and location should be proved by actual test, with a minimum safety factor of 25 percent above the maximum expected charge."

Preliminary tests were designed to determine which materials might be useful in shields; no effort was made to explore the effect of mounting or shield design. Nine materials were tested: transparent materials were Plexiglas[1], safety glass, and glass containing a wire mesh; non-transparent materials were oak board, pine board, sheet metal, plywood, Masonite[2], and Transite[3]. The materials being tested were clamped with C-clamps between heavy angle iron frames (Fig. 25). Each frame with its four clamps weighed 65 pounds and exposed a shield area of 11-1/2 x 17-1/2 inches to the blast. Four frames were generally set to form a hollow square in the center of which an explosive charge was detonated.

Charges consisted of 5, 25, 50, or 125 grams of Composition C-4, which has a TNT equivalent of 1.30 as measured by the ballistic pendulum test[4]. In tests not designed to give fragments the C-4 was contained in a plastic bag, and by using a five foot length of detonating fuse the test sample was not affected by fragments from the No. 8 blasting cap used for initiation. Part of the charges were detonated in glass bottles to provide a measure of the effect of glass fragments. A bottle weighing 17 g. was used with 5 and 25 g. charges and bottles weighing 86 or 107 g. were used with 50 and 125 g. charges. A few charges were detonated in lengths of steel pipes to determine the effect of steel fragments.

[1]Tradename, Rohm & Haas Company, Philadelphia, Pennsylvania

[2]Tradename, Masonite Corporation, Chicago, Illinois

[3]Tradename, Johns Manville Sales Corp., New York, N. Y.

[4]Department of the Army, TM 9-1910, "Military Explosives" April 1955, pp 204 & 324.

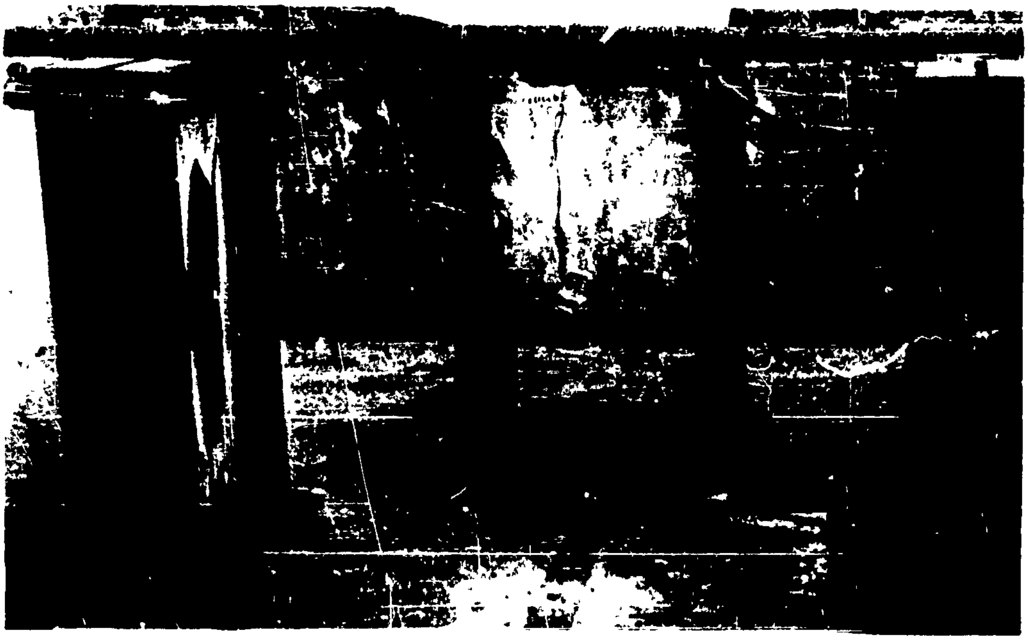

Fig. 25 Clamps used to mount shield materials for tests.

After each test the sample of shield material was examined. If a fragment penetrated the sample, or if it splintered on the side away from the blast, or if it split, cracked, bulged, or broke to the extent that there was an open space between the surfaces, the material was judged to have failed. If the sample had none of these characteristics it was assumed to offer adequate protection. On rare occasions a result was classified as "protected (marginal)", meaning that although the sample did not fail by definition, protection was marginal.

The materials tested failed in various ways; the hazard of the failure criterion in each case may affect interpretation of the results. The criteria are described below and shown in Figs. 26 through 33.

Fig. 26 Typical failure pattern of Plexiglas.

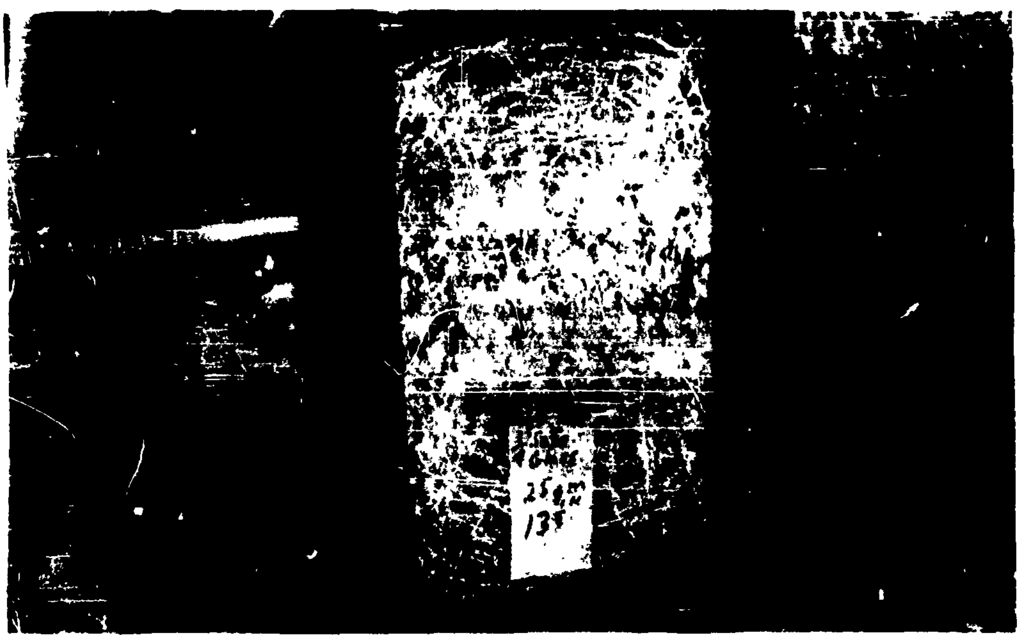

Fig. 27 Typical failure pattern of safety glass.

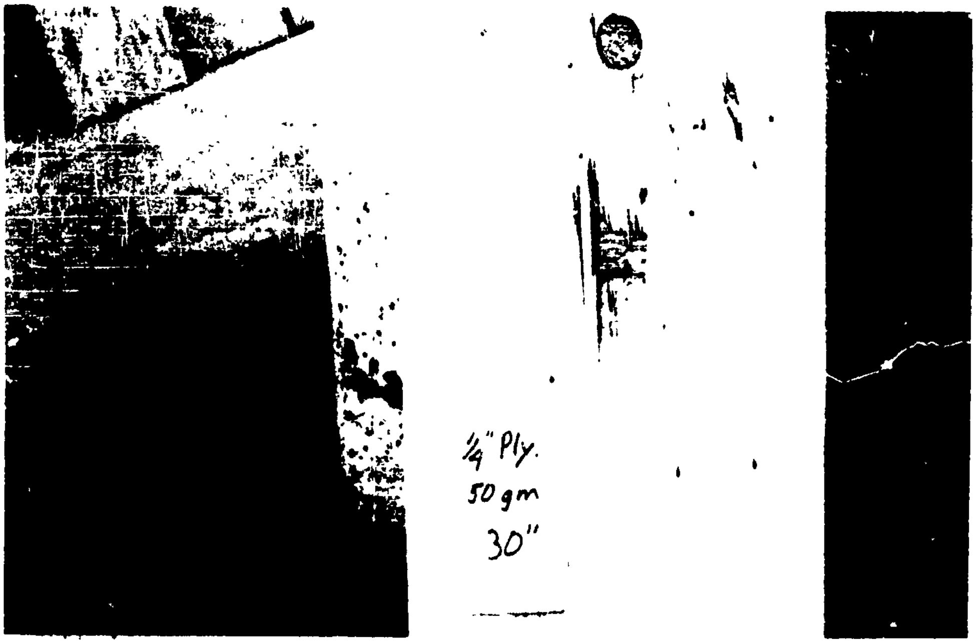

Fig. 28 Typical failure pattern of plywood.

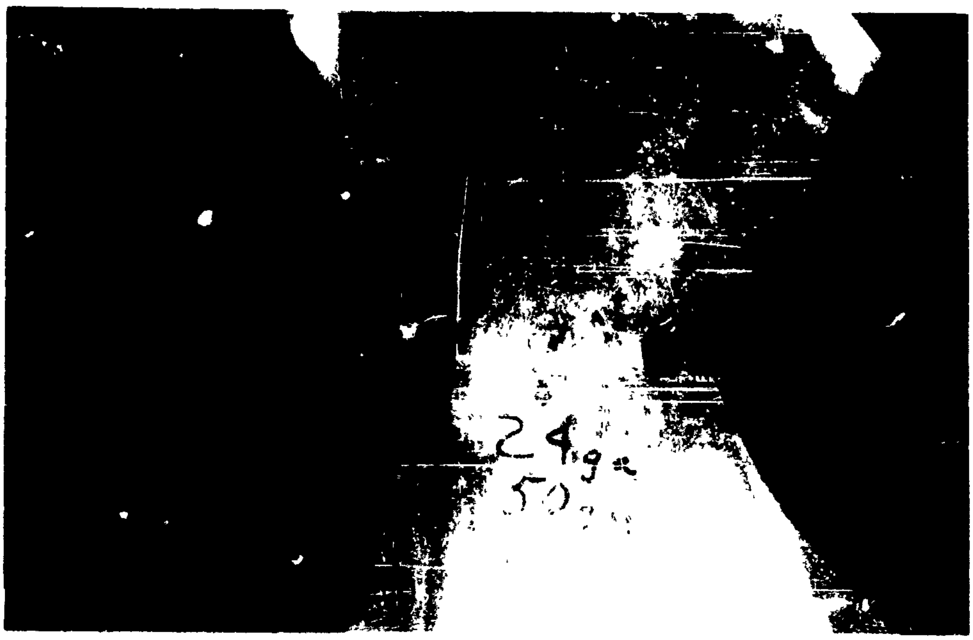

Fig. 29 Typical failure pattern of sheet metal.

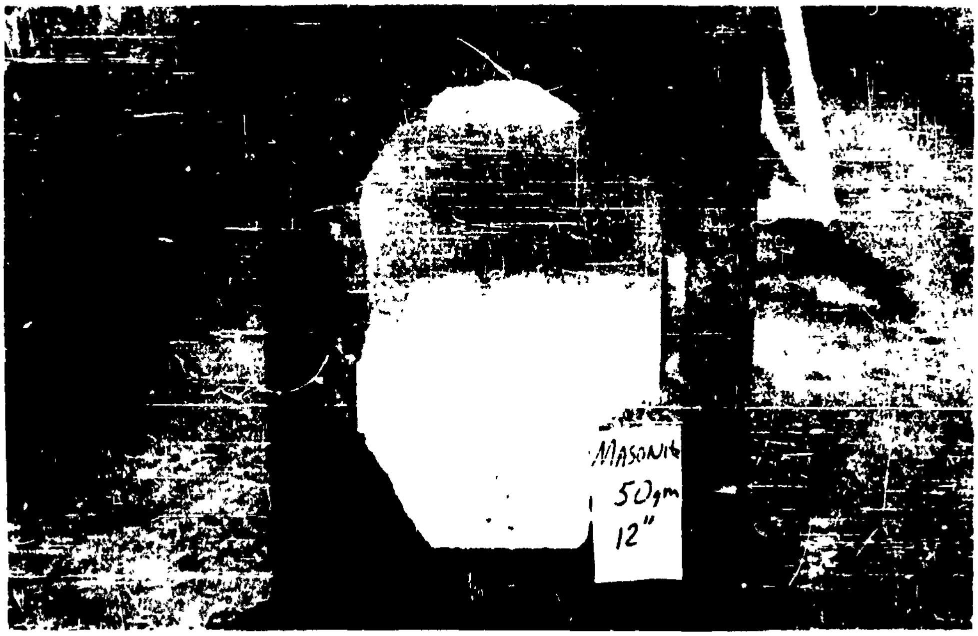

Fig. 30 Typical failure pattern of Masonite.

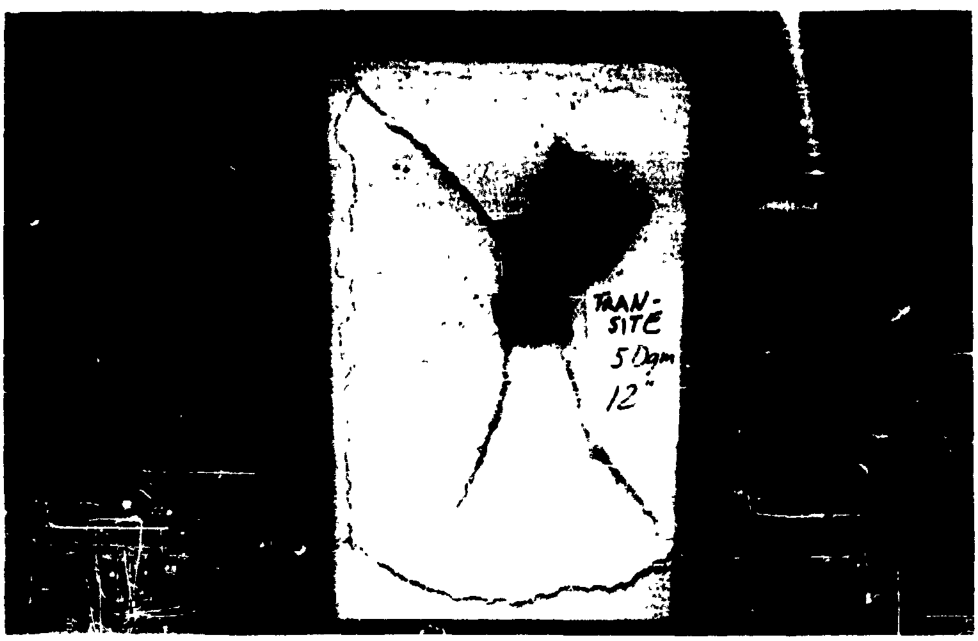

Fig. 31 Typical failure pattern of Transite.

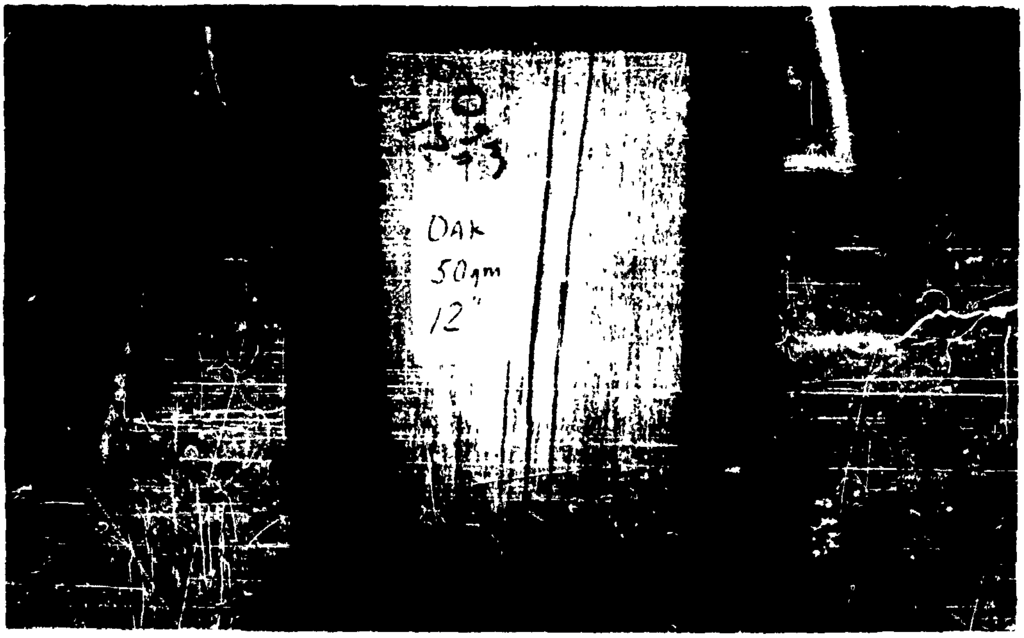

Fig. 32 Typical failure pattern of oak.

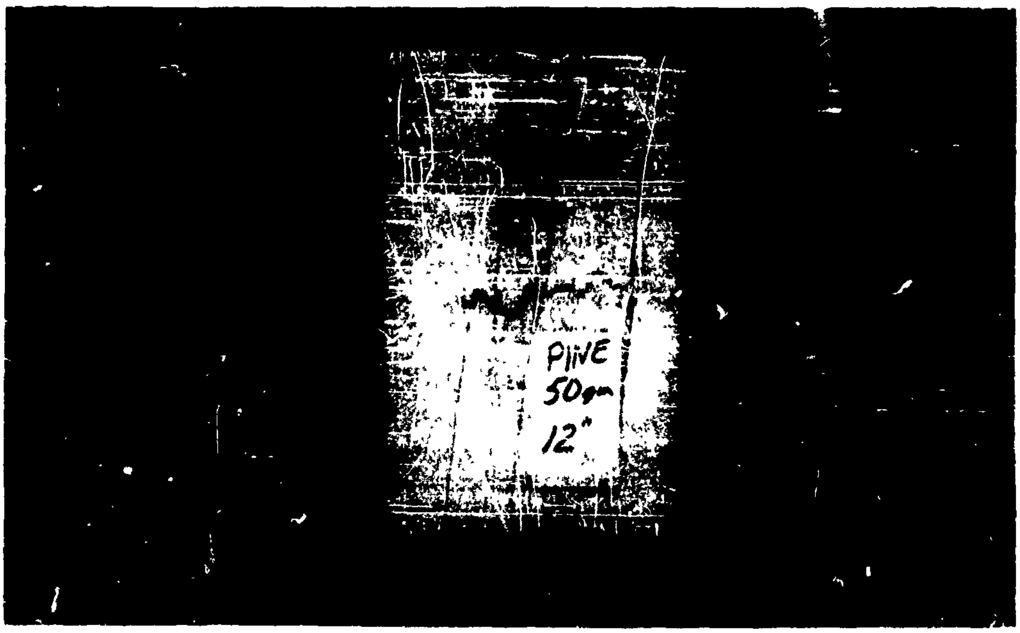

Fig. 33 Typical failure pattern of pine.

(1) Plexiglas failed by cracking and breaking into distinct pieces.

(2) Safety glass and glass containing wire mesh failed by spalling on the side away from the blast.

(3) Plywood failed by penetration of fragments, and was splintered on the side away from the blast.

(4) Sheet metal failed in two ways depending on its thickness: Thin sheet metal was penetrated by fragments, whereas the thicker sheets failed because of excessive bending which pulled the edges from their clamping supports.

(5) Masonite was ruptured by the blast.

(6) Transite was torn by the blast.

(7) Oak and pine failed by splitting.

Detonations and the effects of detonations are not precisely reproducible, and so detonation results are generally reported on a statistical basis. For those materials of major interest (1/4-in. and 3/8-in. Plexiglas) the tests were repeated sufficient times that statistical variation became apparent. For any particular weight of explosive the results obtained were a function of the distance between explosive and shield; at small distances the shield failed consistently, at intermediate distances it failed part of the time, and at greater distances it gave consistent protection (Figs. 34 and 35). Other materials were not tested as extensively as Plexiglas so minimum distances were assigned at which complete protection would be obtained with various weights of explosive (Table III).

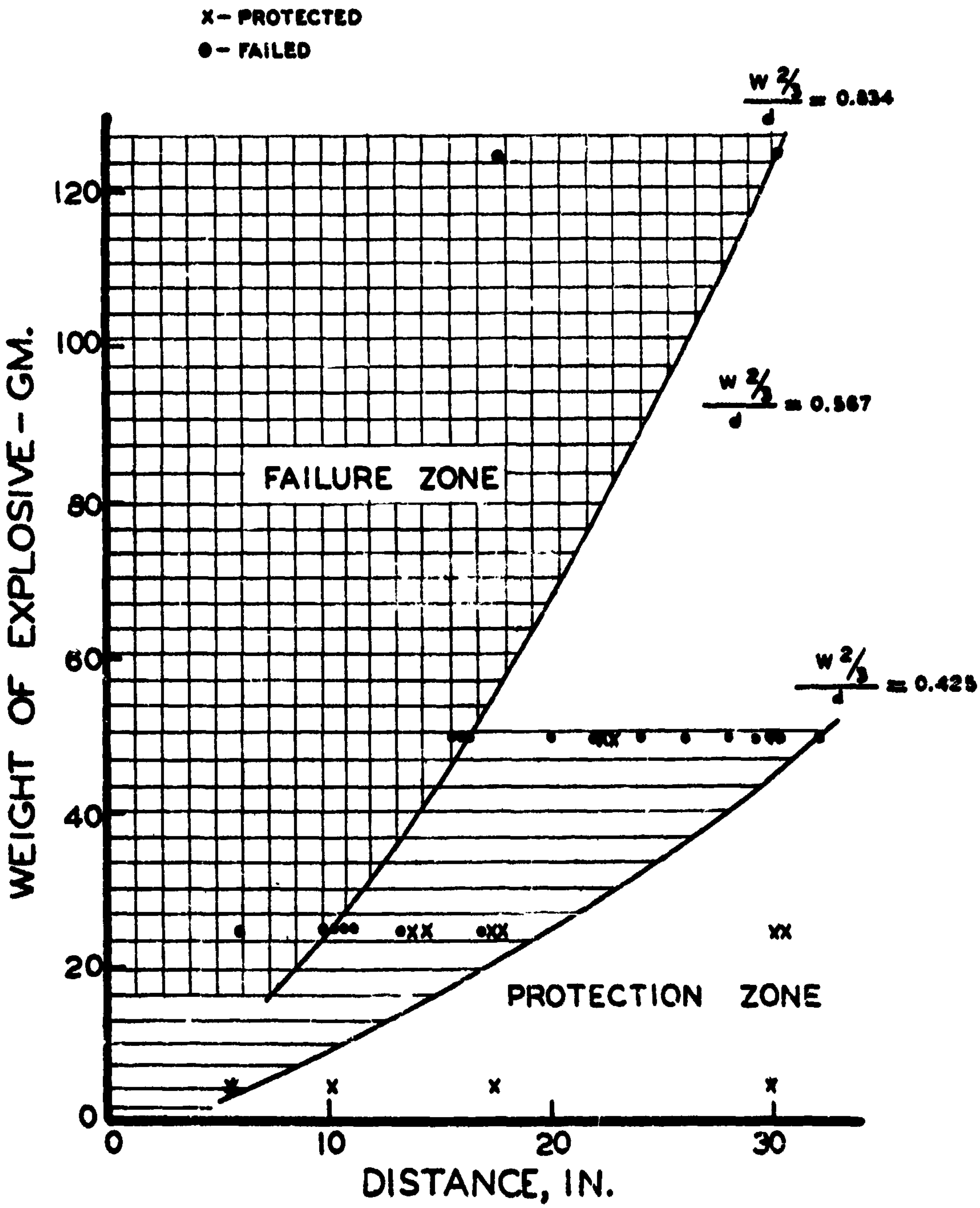

Fig. 34 Minimum distances at which protection is obtained with 1/4 inch Plexiglas.

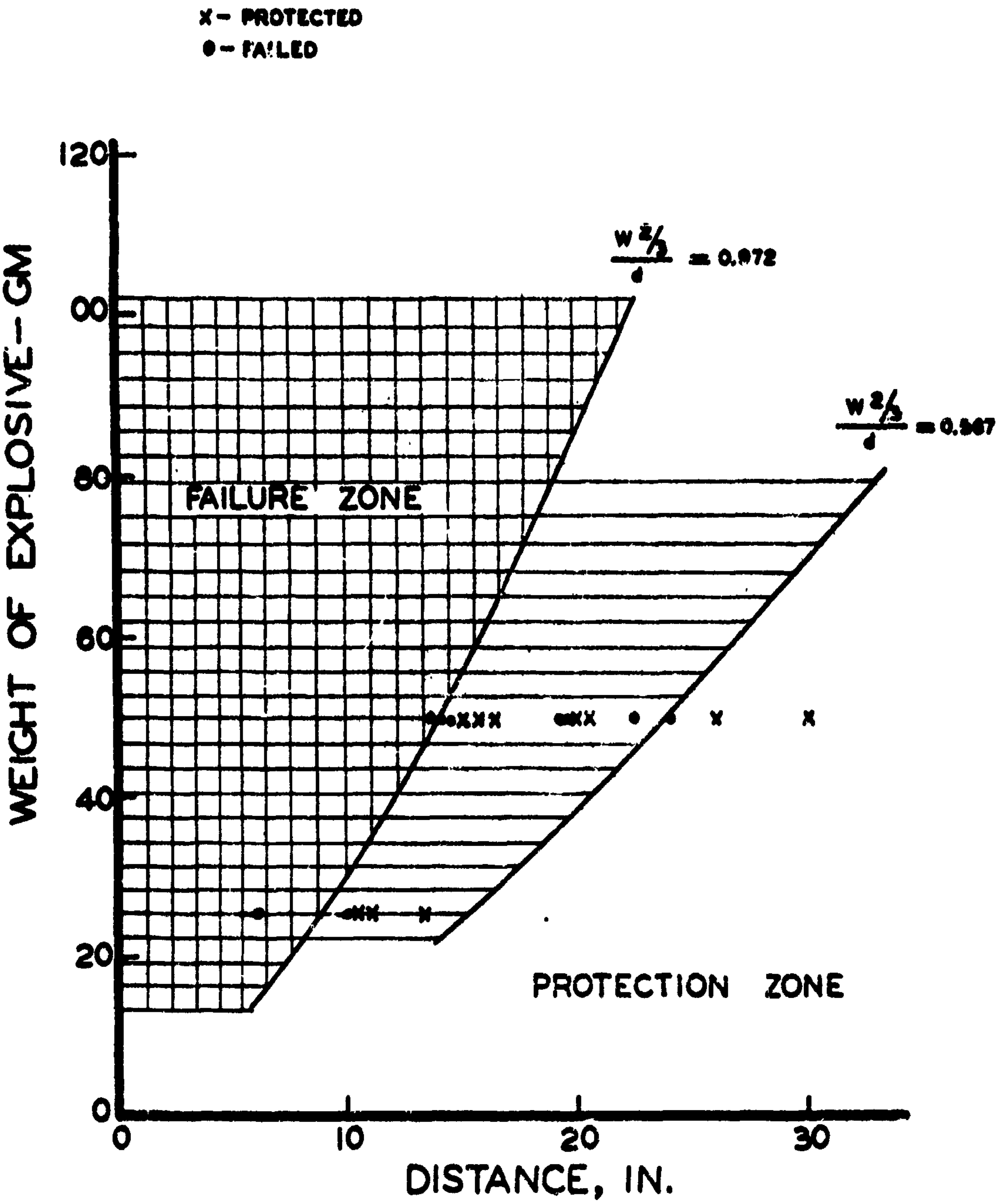

Fig. 35 Minimum distances at which protection is obtained with 3/8 inch Plexiglas.

Table III

Distances at which Various Materials Supply Protection Against the Detonation of Various Quantities of Explosive

	Material Supplies Complete Protection at the Distances Given Below when the Following Quantities of Explosives are Detonated		
	5 g.	25 g.	50 g.
1/4-in. safety glass	10.25 in.	17.5 in.	
1/4-in. Plexiglas	6	30	
3/8-in. Plexiglas		13.5	26-in.
Double 1/4-in. Plexiglas with air space			20
Double 3/8-in. Plexiglas with air space			12
3/4-in. plywood			26
3/4-in. oak board		12	30
3/4-in. pine board		30	
24 ga sheet metal		30	
14 ga sheet metal			6
1/4-in. plywood backed with 24 ga sheet metal		6	
1/2-in. plywood backed with 24 ga sheet metal			6

In the design of safety shields it should be recognized that the protection obtained is influenced by factors other than the shield material. Materials are usually stronger if securely clamped in a rigid frame but without undue stress concentration in brittle materials; flexible materials such as sheet metal are practically useless unless they are securely clamped. There was also evidence that some thought should be given to the methods of fastening down the frame; although the frames used for these tests weighed nearly 70 pounds and were set on concrete they were moved as much as 60 inches by the detonation of 50 grams of Composition C at a

distance of 8 inches. A commercial semicircular laboratory shield 30 inches tall made of 1/4-in. Plexiglas was blown from two ring stands by a 5-g. explosion at 6 inches.

The quantity and kind of fragments in an explosion also had considerable effect on the performance of the shield materials. An increase in the glass bottle weight from 17 to 86 g. increased the damage more than might be expected. Visual examination of the Plexiglas indicated failures around points of impact by fragments. Subsequent fragment-free tests verified this effect. Two shots with Composition C in steel tubing caused appreciably more damage than similar shots in glass bottles.

For fragment-free explosions various equations can be used to give a relation between quantity of explosive and distance; of those equations which were examined the best fit was obtained with the equation[1]

$$\frac{I}{K} = \frac{w^{2/3}}{d}$$

where I/K = impulse

w = charge weight

d = distance from charge

Only for 3/8-inch and 1/4-inch Plexiglas were enough data obtained to allow use of the equation. If the value of $\frac{w^{2/3}}{d}$ was less than 0.567 for 3/8-in. Plexiglas and less than 0.425 for 1/4-in. Plexiglas the shields gave adequate protection. However, these values would vary considerably depending on the type and quantity of fragments, and materials should be tested under the conditions at which they will be used.

[1]Corps of Engineers, "Fundamentals of Protective Design", (1946) p. 3-46.

2. Heavy Duty Shields (50 gm Charge)

A standard laboratory safety shield which would be adequate for use with up to 50 grams of explosive at 6 inches would be highly desirable, and an attempt was made to develop such a shield.

Various thicknesses of Plexiglas (12-in. x 18-in.) were exposed to the detonation of a 50-gm charge of C-4 at a distance of 6 inches. One-inch thick Plexiglas and one-inch thick Plexiglas backed with 1/2-in. thick Plexiglas failed. One-inch thick Plexiglas separated by a one inch air space from 3/8-in. Plexiglas (Fig. 36) protected; the 1-in. Plexiglas was broken, but the 3/8-in. Plexiglas did not break.

These tests indicated that a transparent shield which would give adequate protection against the detonation of 50 grams of material would be so heavy and bulky that it would be used only for special situations, and lighter shields would be used routinely. Since shields for 50 grams of explosive would probably not be portable economies could be effected by using non-transparent materials such as 1/2-in. plywood backed with 24 ga. sheet metal. A sight port made from 1-inch Plexiglas plus 3/8-inch Plexiglas separated by an air gap could be included, but the shield should be tested before use since the mounting of the sight port might be a weak point.

3. Medium Duty Shields (25 gm Charge)

When it became apparent that a safe shield for a 50-gm explosive charge would not be portable, a shield that would adequately protect against a 25-gm charge was investigated.

One-half inch Plexiglas sheets (30-1/2-in. x 14-1/2-in.) were mounted in frames of light weight aluminum angle welded at the corners, and subjected to the detonation of 25-gram charges of explosive contained in a glass bottle. The Plexiglas failed when placed eight inches from the explosive charge; when placed 10 inches from the

Fig. 36 Section from a transparent safety shield which protected against a 50-gram charge at a distance of 6 inches.

charge it failed in one test and protected in one test. The frames were bent and twisted and were not suitable for reuse.

A practical shield design (Fig. 37) having a frame constructed of welded aluminum channel was then tested. This shield containing a piece of 30-in. x 16-1/2-in. Plexiglas gave marginal protection against the detonation of a 25-gram charge at 10 inches and good protection at 12 inches.

In some cases it is desirable to remotely manipulate various pieces of equipment situated behind a shield. Since the manipulator is most conveniently mounted by passing it through the shield material tests were made to determine whether the shield would be weakened significantly. The manipulator was passed through a brass ball which was confined between two brass plates designed to be set on each side of the shield. In the first test a hole having the same diameter

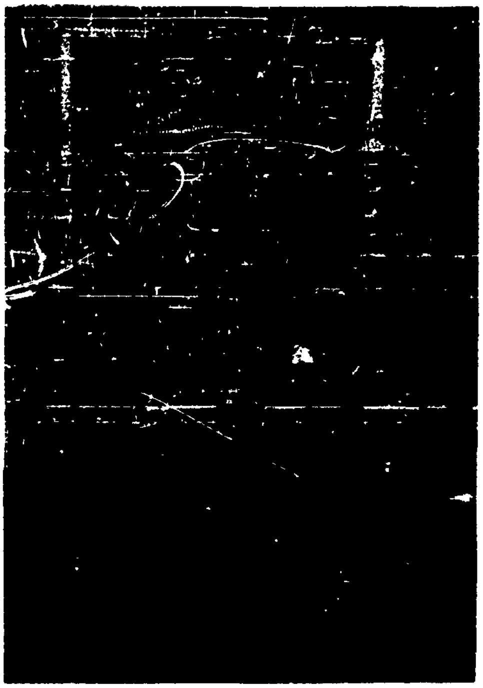

Fig. 37 Shield design with welded aluminum channel frame.

as the brass ball was drilled through the Plexiglas and four small holes were drilled to accommodate screws set in each corner of the brass plate. When subjected to the detonation of 25-grams of explosive at a distance of eight inches the shield failed badly, cracking through each of the four holes and in other places. The brass insert and ball-joint fixture, which weighed 1.65 lb, were blown approximately 45 feet from the shield.

In the next test the hole through the Plexiglas was made large enough to clear the attaching screws. When subjected to the detonation of 25-grams of explosive at 8 inches the ball-joint fixture remained clamped in the shield but the Plexiglas broke in several places including a radial break from the edge of the hole.

In the final design the manipulator fixture was mounted in an aluminum plate between the two sides of a V-shaped

shield (Fig. 38). The shield gave adequate protection against the detonation of 25 grams of explosive at a distance of twelve inches. In a second test a glass bottle containing 25 grams of explosive was clamped in the manipulator. When the explosive was detonated at a distance of 12 inches the manipulator rod was not damaged and was moved toward the operator's side of the shield only a few inches.

When shields were exposed to the detonation of 25-gram charges they were always knocked over and in some cases were moved as much as 30 to 40 inches from their original position. To determine the force with which the shield was knocked over a high speed movie was made of one test; this indicated that the shield began to topple about 60 milliseconds after the initial blast and was knocked down within 150 milliseconds. Shields used to protect aga. .st 25-gram quantities should be securely fastened.

4. Swinging Shields

Swinging shields suspended from the ceiling are frequently used to shield large pieces of apparatus. A swinging shield of 32 x 22 x 1/4-in. Plexiglas afforded good protection against the detonation of 5 grams of explosive in a glass bottle at a distance of six inches.

A double shield consisting of two sheets of 32 x 22 x 1/4-in. Plexiglas spaced 4 inches apart was subjected to a 25-gram charge detonated 6 inches from the closest sheet. Both sheets failed. The back sheet was hung by strapiron secured to the Plexiglas and bent over a piece of angle (Fig. 39) so that an unnecessarily large bending moment was applied to the shield. A shield which had more freedom to swing might not have been broken.

Swinging shields made of safety glass and a 36 x 48 x 1/2-in. sheet of Plexiglas were broken by the detonation of 50 grams of explosive at a distance of 12 inches.

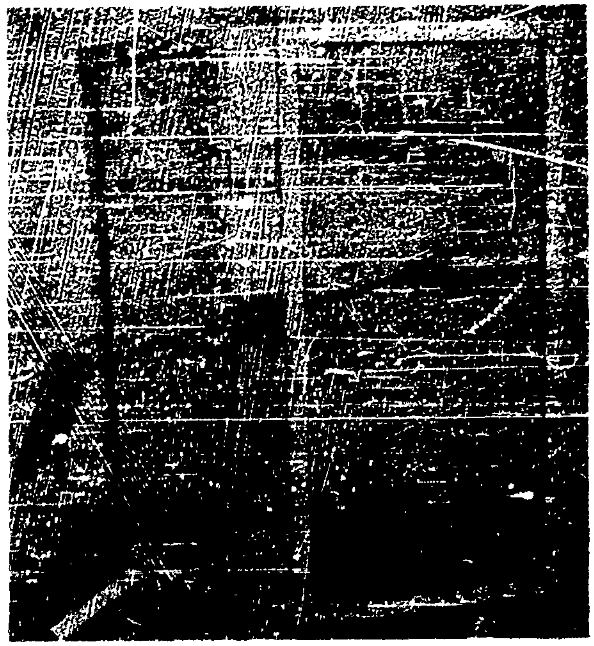

Fig. 38 Shield with manipulator mounted in an aluminum plate.

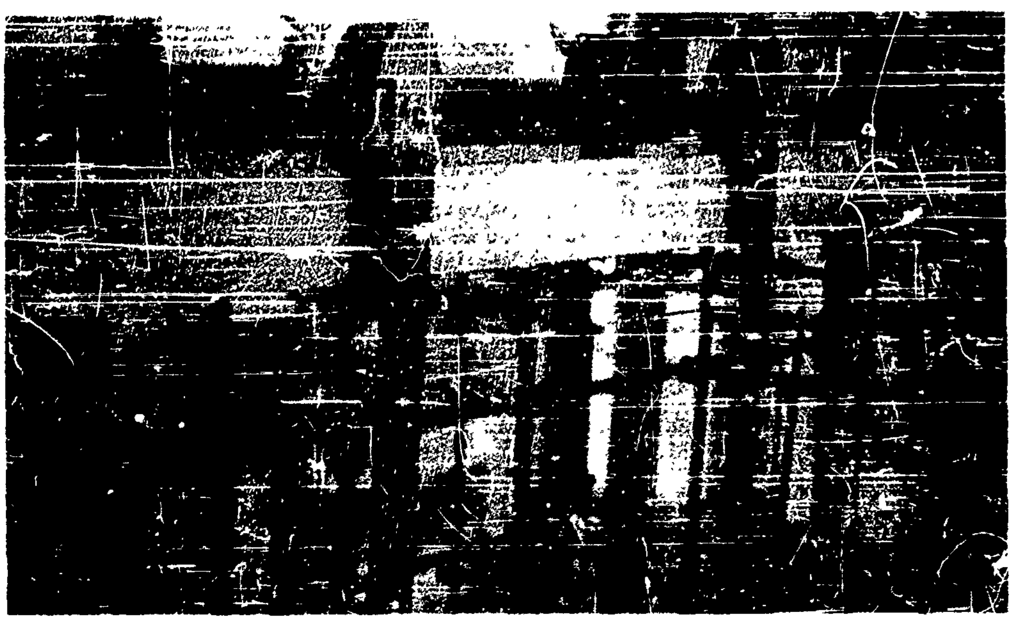

Fig. 39 Mounting of swinging shield.

C. Gloves

In an explosives laboratory gloves are frequently used to protect against the possible explosion of small quantities of material held in the hand or located near the hand. Since gloves are not normally designed or tested for such applications a test procedure was developed to measure the degree of protection obtained with various commercially available gloves.

Copper wire (0.033 inches in diameter) was doubled and twisted together to form fingers and the framework of a hand. Polyethylene film was rolled and placed over the wire as a substitute for flesh on the fingers. The test glove was then placed over the substitute hand, and glove and hand were placed over a 1-in. x 2-in. piece of wood which was clamped in a ring stand. A 16 x 150 mm test tube was placed in the palm of the glove (Fig. 40) and the testing device inserted in the test tube. A number six electric blasting cap, a number eight electric blasting cap, and a short length of detonating fuse were tested for explosive effect. The cotton glove used for these tests was shredded by the number eight cap and the detonating fuse so all tests were made with a number six cap.

The gloves tested are listed below and glove damage is shown in Figs. 41 through 47.

Types of Gloves Tested

	Type	Supplier or Manufacturer
1.	Lineman's Glove (leather)	W. H. Salisbury & Company
2.	Brotherhood Glove (yellow cowhide)	Wells Lamont Corp.
3.	White Cotton Glove	General Services Administration
4.	Neoprene Coated Glove (cotton)	Stark Industries
5.	Steel Reinforced Glove (leather)	Mine Safety Appliances Co.
6.	Asbestos Glove	Allied Industrial Glove Corp.
7.	White Mul Glove (horsehide)	General Services Administration

Fig. 40 Method used for testing the effect of explosions on gloves.

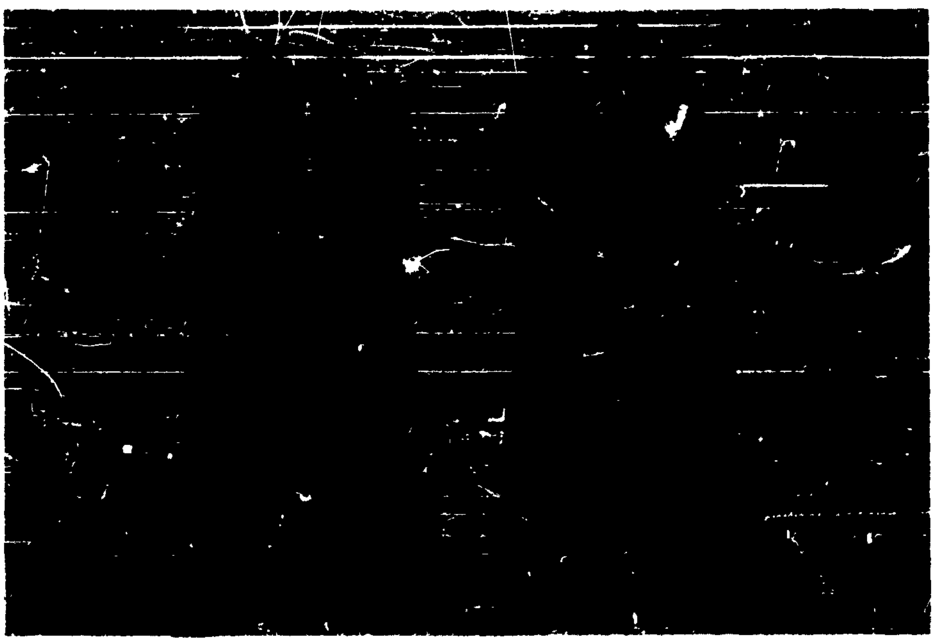

Fig. 41 Leather lineman's glove after test (left)

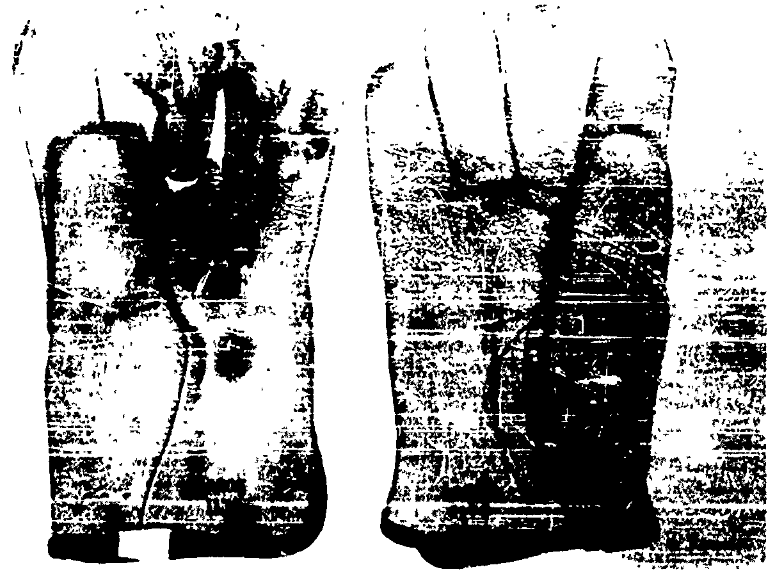

Fig. 42 Brotherhood glove (yellow cowhide) after test (left)

Fig. 43 White cotton glove after test (left)

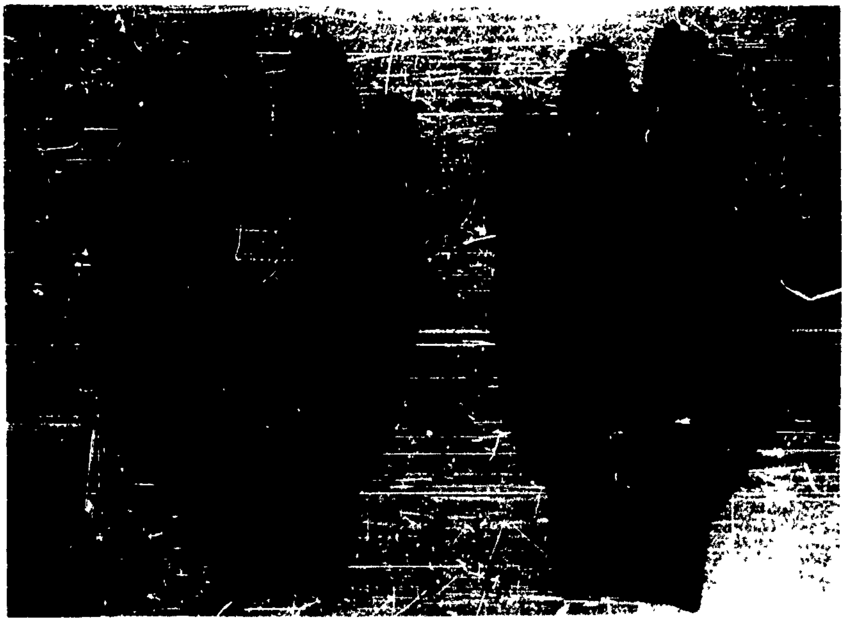

Fig. 44 Neoprene coated glove after test (left)

Fig. 45 Steel reinforced leather glove after test (left)

Fig. 46 Asbestos glove after test (right)

Fig. 47 White Mule horsehide glove after test (right)

III. Protective Devices

A. Sample Transporting Containers

While adequate shields provide protection from reactions carried out in fixed equipment there are occasions when transportation or movement of possibly sensitive materials is necessary. Two explosives carriers were built, one for fairly large pieces of equipment, and the other primarily for vacuum vessels containing cold traps.

The large explosives carrier (Fig. 48) consisted of an aluminum cylinder 18 inches in diameter, 35 inches long with 3/8-in. thick walls mounted on a dolly to allow easy movement. The bottom was open and the top was closed with a removable 1/4-in. aluminum plate perforated with a number of small holes. A slot was cut in the side to allow the cold trap which would customarily be located inside the carrier to be connected to a vacuum line. A cup and ring were provided to hold the trap and could be raised or lowered by a rod outside the carrier.

Detonation of 50 gm. of Composition C-4 in a 250-ml flask below the ring inside the container produced considerable damage. Detonation of 10 gm. of Composition C-4 adjacent to the carrier cup and ring blew out the bottom of the cup and broke the ring. Witness screens showed that some blast hazard existed within about a foot of the bottom of the container. Small particles were ejected through the top and the side slot. It was concluded that the detonation of 10 grams of high explosive could be contained although fragments might present a small hazard to nearby personnel.

The small transporter (Fig. 49) was designed for movement of small samples and as a fixed shield for traps on vacuum lines. It consisted of a 14-inch length of 4-in. seamless stainless steel tubing with a welded bottom and a carrying handle. Testing showed that the container could withstand the detonation of five grams Composition C-4. It should be noted that the strength of the container would be much less if it were made of tubing having a welded seam.

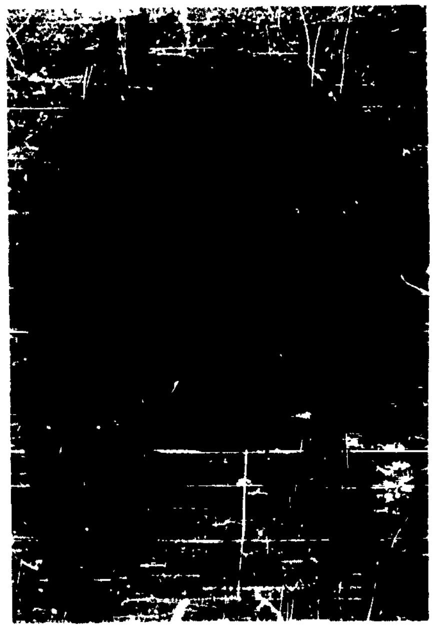

Fig. 48 Side view and top view of large explosives carrier.

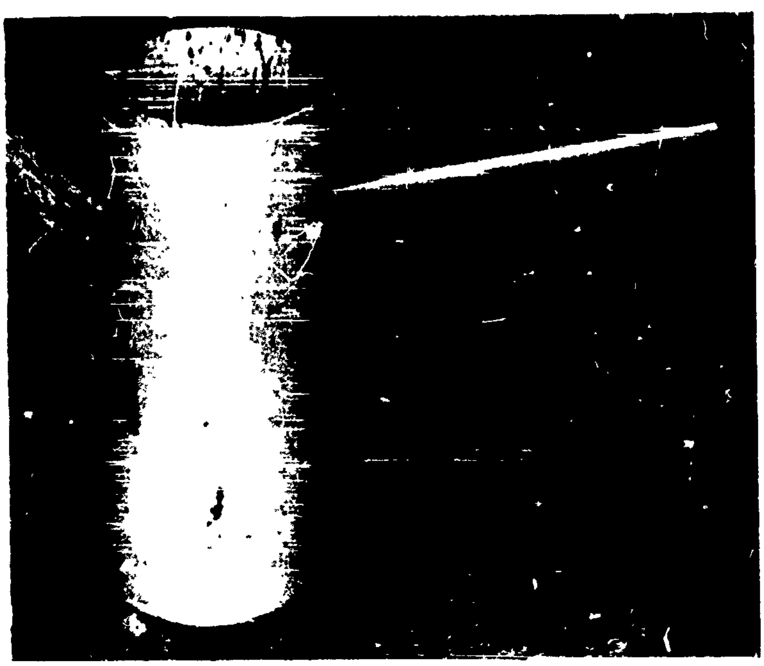

Fig. 49 Small sample carrier.

B. Remote Manipulators (Laboratory Experiments)

Remote manipulation devices can be used to reduce the exposure of personnel conducting reactions behind laboratory safety shields or carrying small quantities of potentially explosive materials. Four remote manipulators were designed and built by this Division. The first (Fig. 50) consisted simply of a laboratory clamp equipped with a hand grip and a shield. The second (Fig. 51) provided a means for opening and closing the clamp remotely. The third (Fig. 52) was designed for turning stopcocks in a fixed location. The fourth (Fig. 53) was a modified pickup tool. The wire connecting the jaws with the handle was replaced with a piece of flexible cable allowing the jaws to be rotated. The manipulator was most conveniently attached to the edge of the shield for manipulation although it could be hand held if it was used for a series of operations.

A commercially available manipulator manufactured by the Harwell Company, London, England (Fig. 54) was tested for handling beakers and flasks. This device like those shown in Figs. 50 and 51 simply increases the distance between the operator and a potential explosive.

An air cylinder (Fig. 55) was adapted for remotely raising and lowering a cold trap behind a shield. Reaction temperatures can be controlled quite conveniently in this way without exposing personnel.

Fig. 50 Device designed for hand protection while carrying flasks or other vessels containing explosives.

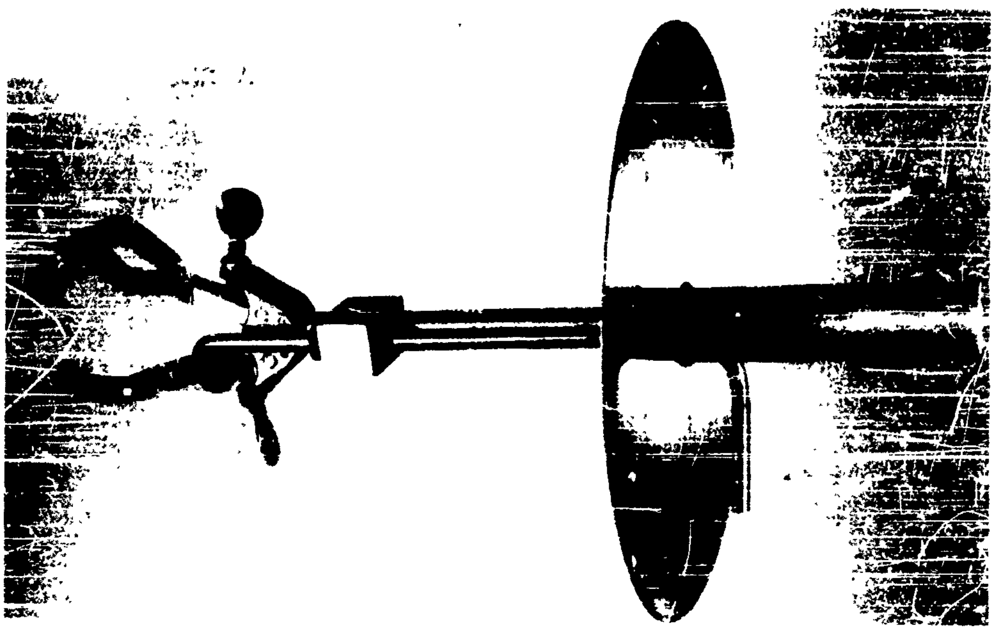

Fig. 51 Device designed for remote manipulation of beakers, flasks, or other laboratory vessels.

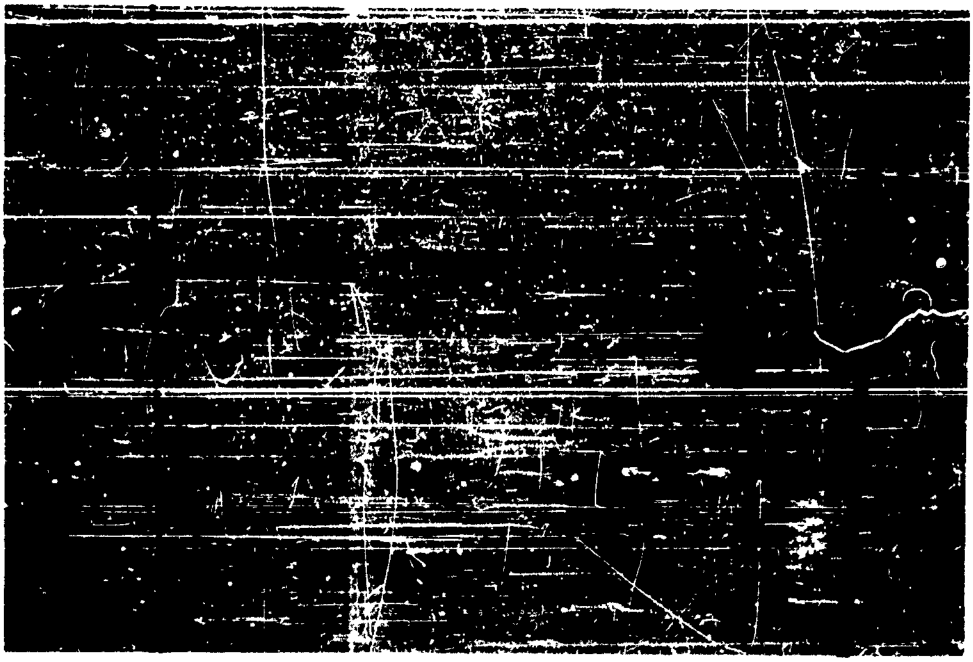

Fig. 52 Device designed for remote manipulation of stopcocks.

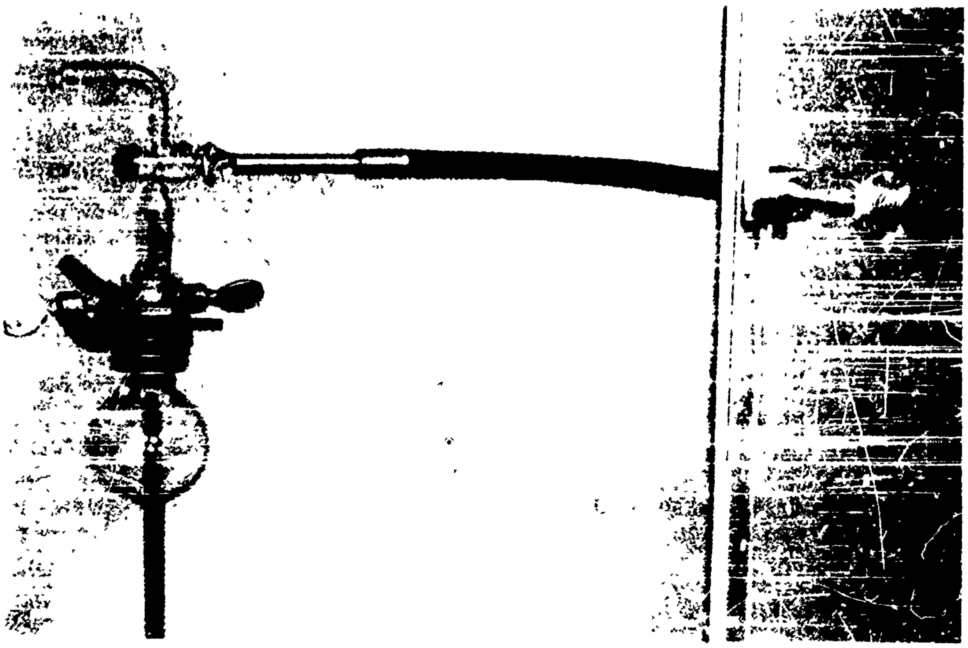

Fig. 53 Manipulator designed for maximum flexibility

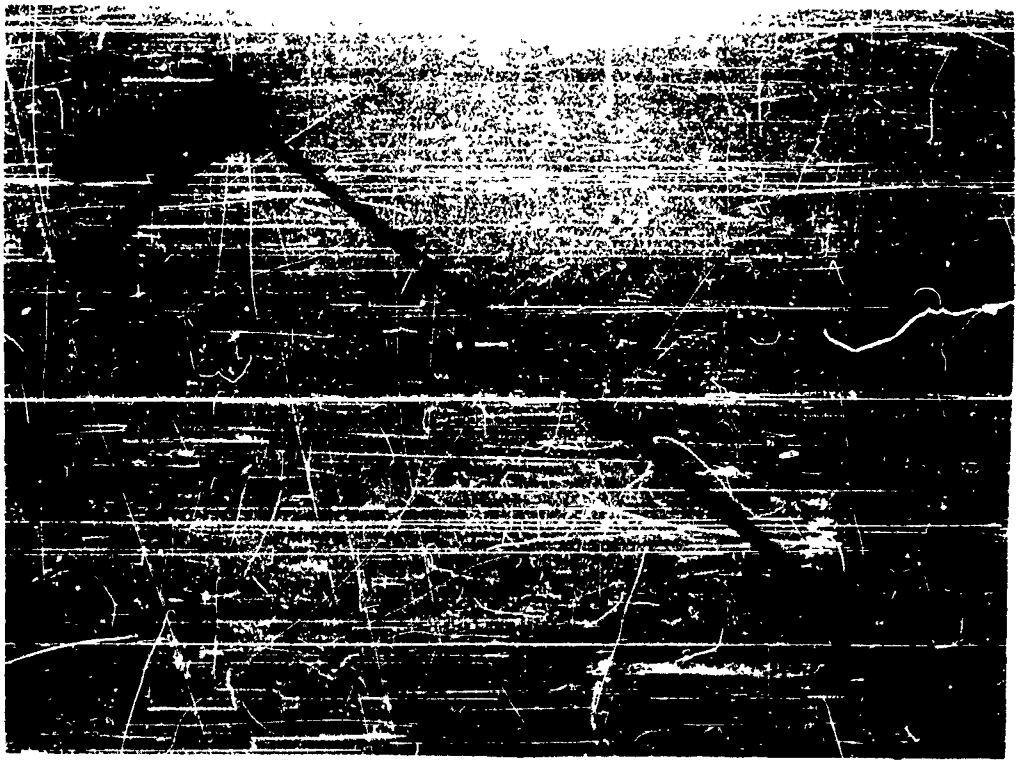

Fig. 54 Tongs manufactured by the Harwell Company.

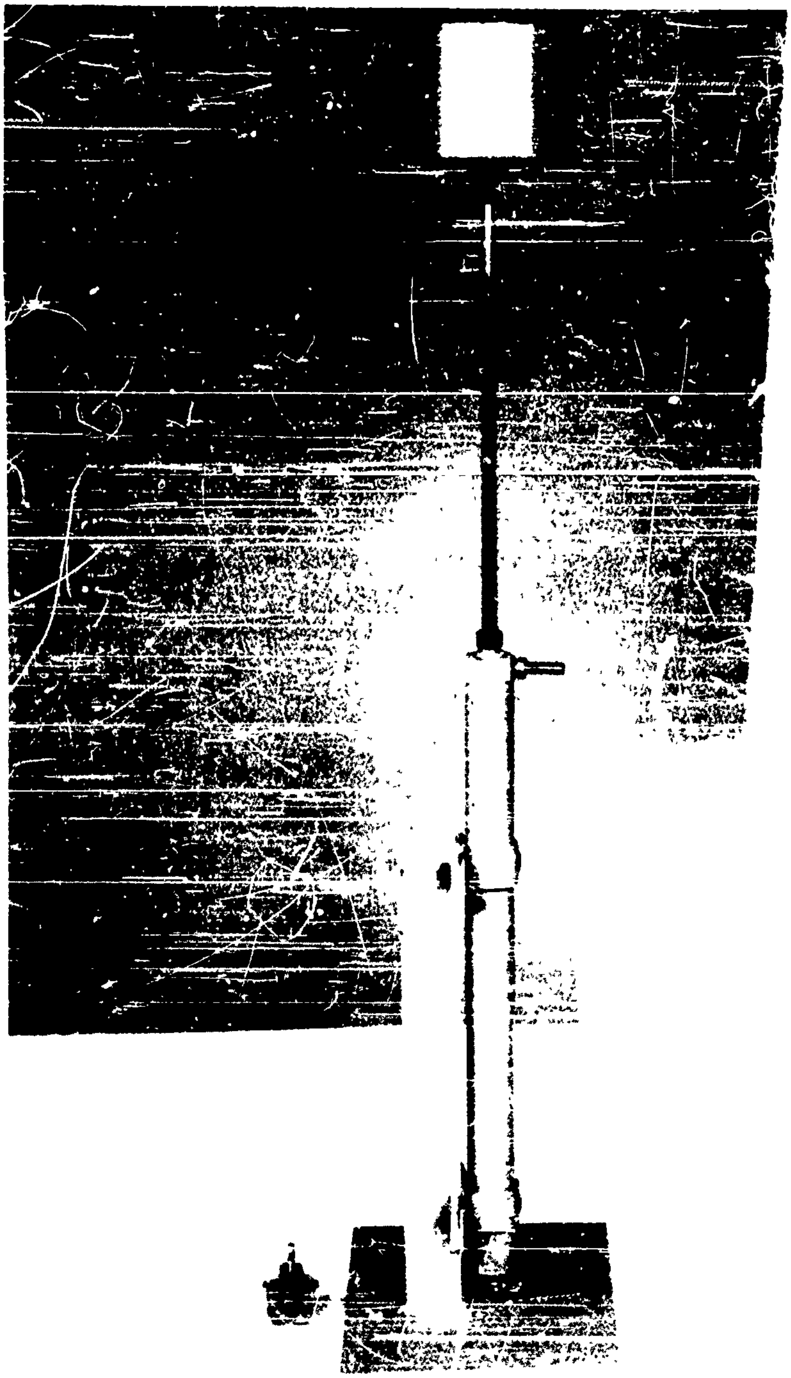

Fig. 55 Remotely operated device for rais